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GB 2123567 A GB 1496151 A US 5463317 A

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INT CL^6 G01R 27/16 27/18 27/20 31/00 31/02 31/08
Online: WPI

(54) Cable testing arrangement

(57) A cable fault detecting arrangement comprises an oscillator 11 connected to an electrode 6 of a cable 4 such that the cable forms an impedance (inductance or capacitance) element of an oscillating circuit. The oscillating circuit produces a test signal (F Test) at a frequency which is dependent upon the condition of the cable and from this frequency it is detected if the cable is faulty. The oscillating circuit may include one or more termination impedance elements CT connected across an end of the cable and may be arranged such that the fault detecting arrangement operates within a bandwidth outside that of the sensor operation. By filtering signals the sensor and fault detection activities may operate simultaneously without interfering with one another. A direct current offset voltage may be applied to the cable to detect cable leakage currents between electrodes 6, 8. The arrangement may be used on a piezoelectric cable for sensing the presence of someone within the seat of a vehicle.

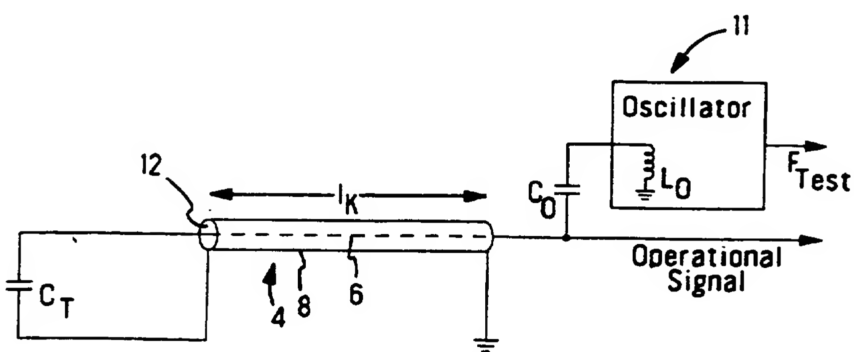

Fig. 4

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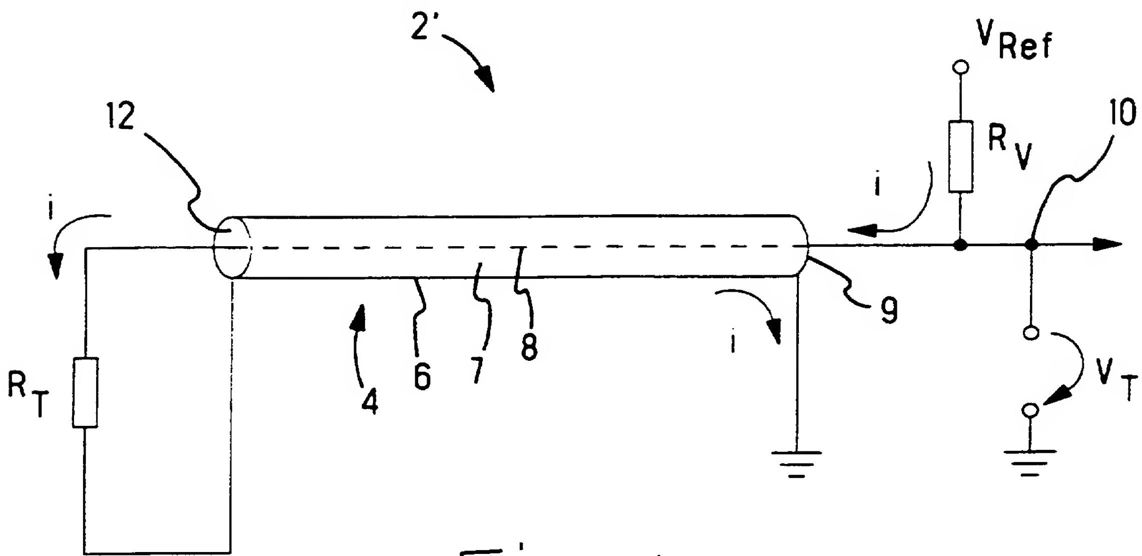
2'
V_{Ref}
12
R_V
10
i
i
9
i
R_T
6
7
8
4
V_T

Fig. 1

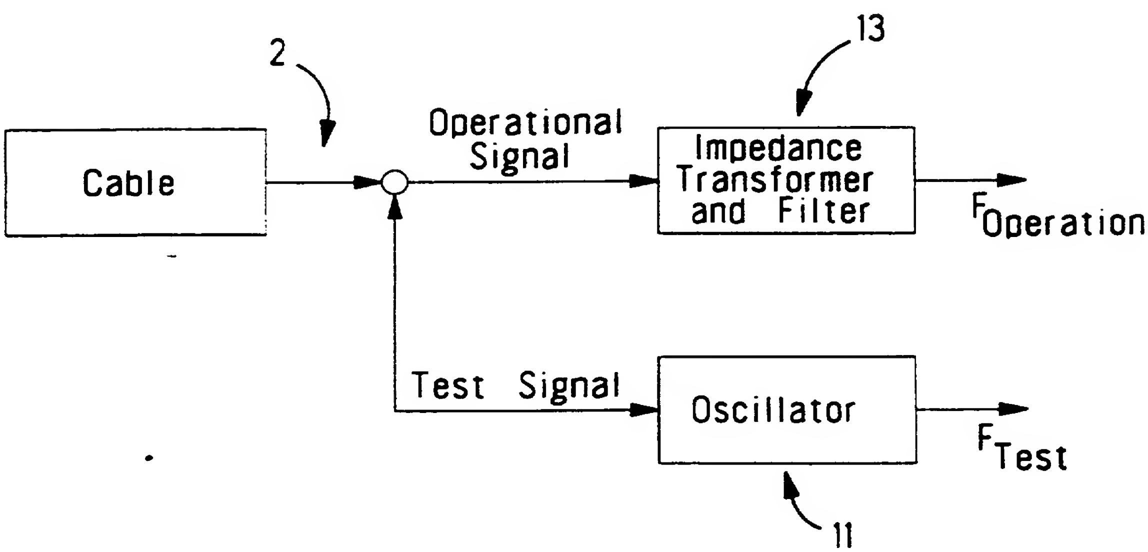
13
2
Operational Signal
Cable
Impedance Transformer and Filter
$F_{Operation}$
Test Signal
Oscillator
F_{Test}
11

Fig. 2

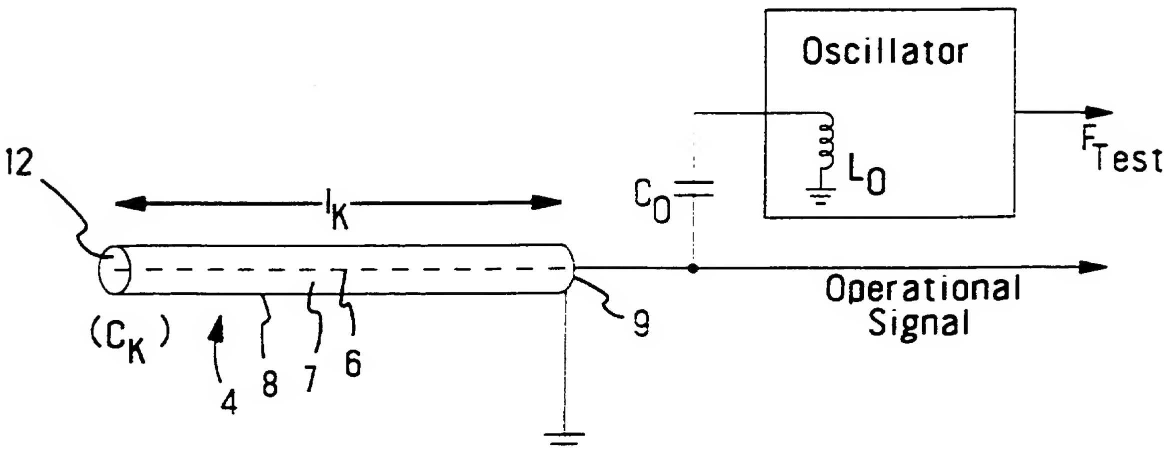

Fig. 3

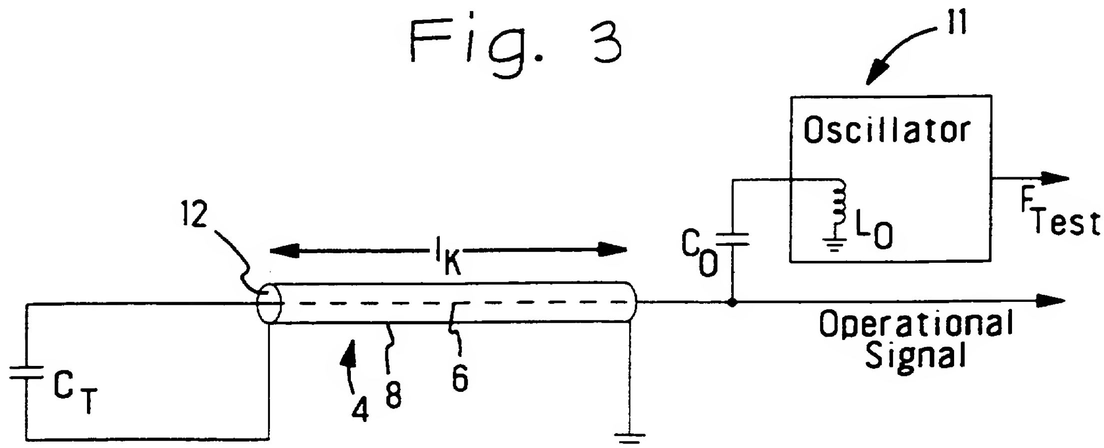

Fig. 4

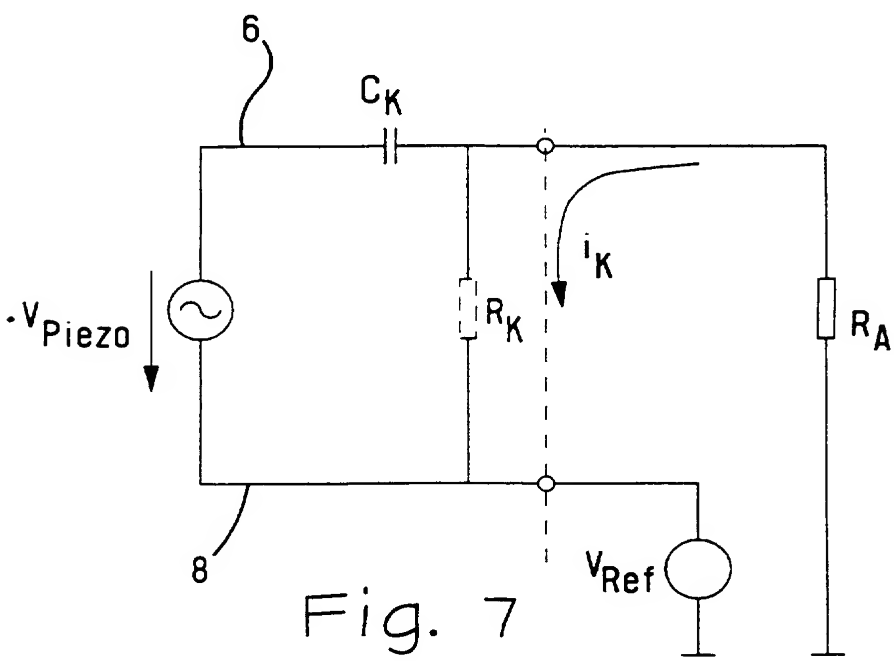

Fig. 7

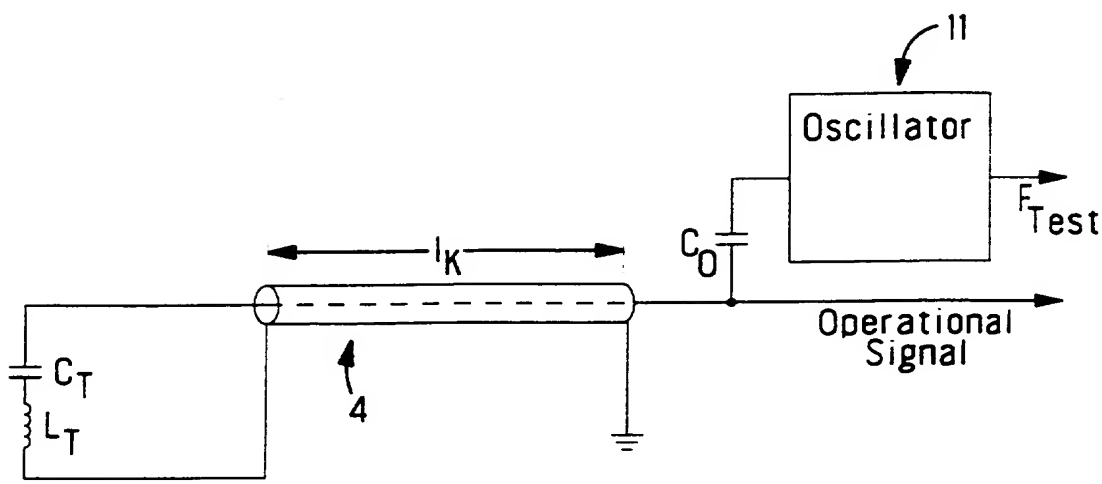
11
Oscillator
F_{Test}
l_K
C_O
C_T
L_T
4
Operational Signal

Fig. 5

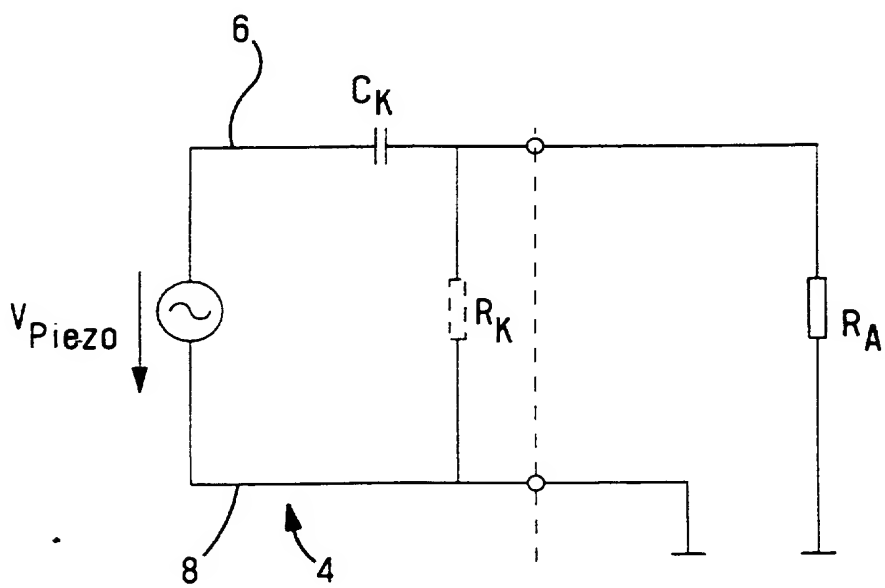
6
C_K
V_{Piezo}
R_K
R_A
8
4

Fig. 6

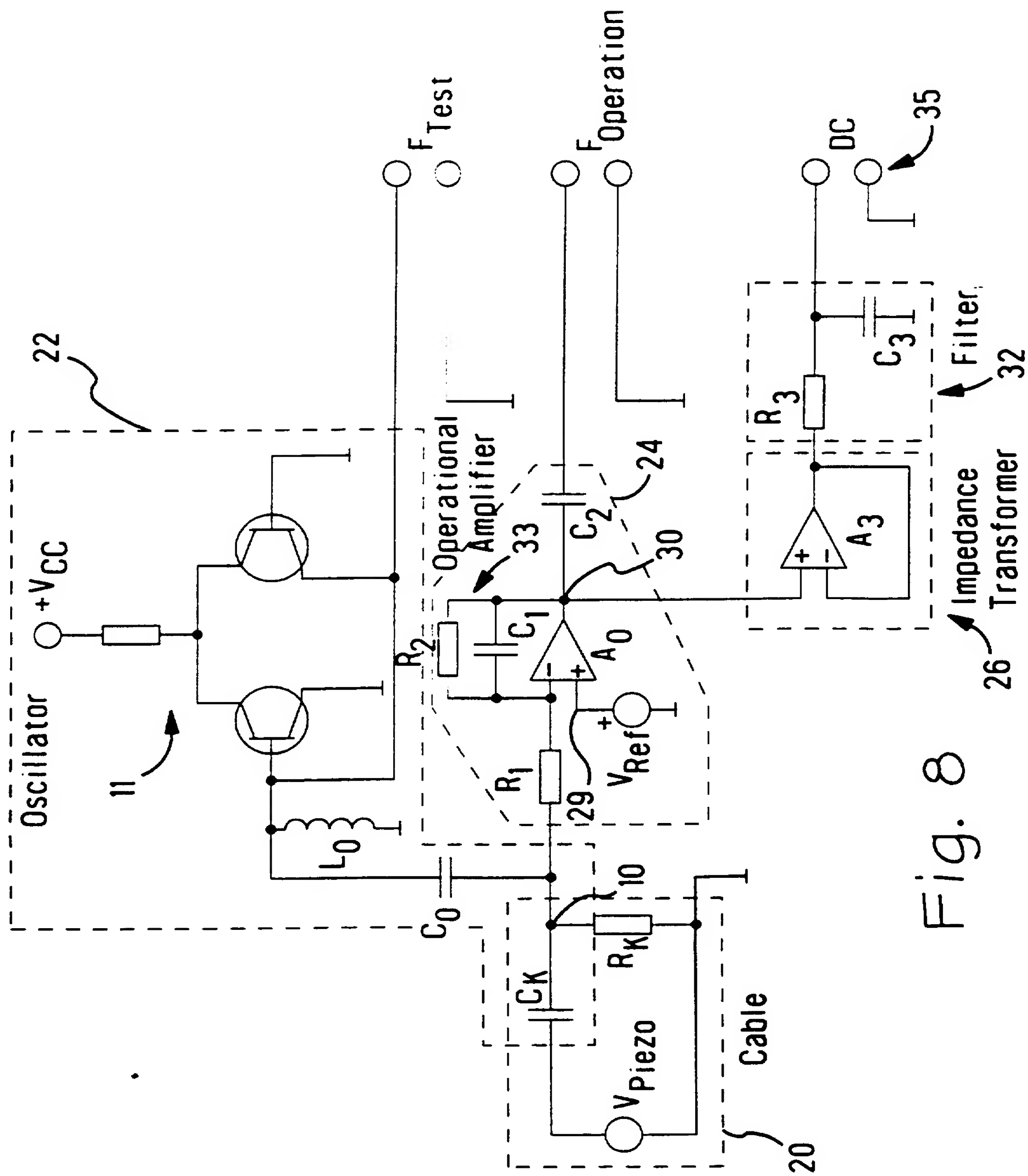
22
Oscillator
11
+V_{CC}
L_0
C_0
F_{Test}
$F_{Operation}$
DC
35
Operational Amplifier
33
R_2
C_1
A_0
C_2
24
30
R_1
29
+
V_{Ref}
10
R_K
C_K
V_{Piezo}
Cable
20
R_3
C_3
Filter
32
A_3
Impedance Transformer
26

Fig. 8

MEANS FOR SELF-TESTING PIEZOELECTRIC CABLE AND A METHOD THEREFOR

This invention relates to a means for testing whether a piezoelectric cable sensor is undamaged and operating correctly.

In many instances sensors require a self-test or self-diagnosis function to ensure correct functioning. For example in the automotive industry, sensor devices that trigger safety functions such as airbags need to be particularly reliable and fail-safe. In U.S. patent 5,404,128 a presence detecting sensor positioned in a seat of a vehicle to detect the presence of a human being is disclosed. The sensor is interconnected to control means that control functioning of the vehicle. The sensor is a piezoelectric element for detecting vibrations and is provided with a self diagnosis function. One of these self diagnosis means is to position a termination resistance between electrodes, and pass an electric current through the sensor. If the sensor is severed, this can be detected as the circuit is open no current flows. If a short circuit occurs along the sensor, this is also detected by the zero voltage drop thereacross. Another self test means proposed is the provision of a vibration generation means in the form of another portion of piezoelectric material, whereby the response of the sensor is detected. The latter self-test is inappropriate for piezoelectric coaxial cable sensors as implemented in U.S. patent 5,164,709., which describes the use of such cable as a presence detecting sensor in an automobile seat. The former self-test means could be implemented in a piezoelectric coaxial cable, however there are certain configurations of damage to the cable that would not be appropriately detected by provision of a termination resistance only. For example, reduced insulation resistance between outer and inner

electrodes due to ingress of humidity may not be correctly diagnosed by a sensor cable with termination resistance.

It is therefore an object of this invention to provide a reliable means for self-diagnosis of a piezoelectric sensor cable.

It would be advantageous if self-diagnosis could occur in parallel to normal operation of the sensor cable.

It would be advantageous to provide a self-testing means that can be very simply and easily integrated into electronic processing means provided for airbag activation.

Further objects and advantageous features will be apparent from the description, drawings and claims.

Objects of this invention have been achieved by providing the cable self-diagnosis means according to claim 1. In particular, the objects of this invention have been achieved by providing a sensor device comprising a sensor cable having electrodes separated by a dielectric, and self-diagnosis means, the self-diagnosis means comprising an oscillator circuit connected to an electrode and adapted to oscillate, thereby producing a test signal (F_{test}) at a frequency determined by the integrity of the sensor cable for detection of damage thereto, the cable providing inductance or capacitance (C_K, C_T, L_T) forming part of the oscillator circuit.

Advantageously, a self-testing means for piezoelectric cable is provided, whereby damage such as severing of the cable is detected in a simple and reliable manner.

It is also advantageous that the self-testing means can be operated in parallel to normal operation of the sensor without interfering therewith. This is particularly important in certain applications where the detecting means must operate extremely rapidly such as in automotive airbag applications. The latter can be achieved by operating the self-diagnosis circuit at a frequency that is outside the

operational band width of the sensor, whereby interference is avoided by the provision of appropriate filtering.

A further advantageous feature could be the provision of a direct current (DC) offset voltage between electrodes of the sensor cable, such that a reduction of dielectric resistance can be detected. In a further advantageous embodiment, provision of a termination capacitor would ensure that the sensor cable is intact over its whole length in an easily detectable manner.

Further advantageous aspects of this invention will be apparent from the following description, drawings and claims.

Embodiments of this invention will now be described, by way of example, with reference to the accompanying **drawings in which:**

Figure 1 is a schematic representation of a sensor cable with a self-diagnosis electrical circuit, the sensor being provided with a termination resistance;

Figure 2 is a block diagram representing the self-testing function of an embodiment according to this invention;

Figure 3 is a schematic circuit representation of a sensor with self-diagnosis means according to this invention;

Figure 4 is a schematic representation of another embodiment;

Figure 5 is a schematic representation of yet another embodiment;

Figure 6 is an equivalent circuit diagram of a sensor, for example as represented in figures 3 or 4;

Figure 7 is a circuit diagram similar to figure 6, but with provision of an offset direct current voltage means;

Figure 8 is a circuit diagram of the sensor and analyzing means.

Referring to figure 1, a sensor 2' is shown comprising a piezoelectric coaxial cable 4 having an outer electrode or conductor 6 and an inner electrode or conductor 8 separated

therefrom by a dielectric 7. At a first end 9 of the cable, the inner electrode 6 is connected to a reference voltage V_{ref} through a resistance R_v, and the outer electrode is connected to earth (ground). An electrical current(i) flows through the cable which is provided at the other (second) end 12 with a termination resistance R_T connected between the outer and inner electrodes. A potential difference at the first end 9 can be measured between the inner electrode 8 at point 10 and ground, such voltage being the test voltage V_T . If the cable is severed, no current flows and $V_T=V_{ref}$. In normal operation, if $R_T=R_V$, then V_T will simply be V_{ref} divided by 2. A severed cable can thus be easily detected. A partially damaged cable may however not be detected. For example when the outer electrode is partially damaged or the dielectric resistance between outer and inner electrodes is affected by humidity a current may nevertheless still flow through the circuit. Furthermore, the capacitance of the cable (C_k) and the resistance R_v, R_t act as a 'high pass' RC filter. For short cable lengths, the capacitance of the cable is low, which increases the cut-off frequency of the 'high pass' filter. When operational frequencies generated by the piezo cable are of a low frequency, it is necessary to provide very large resistance values for R_t,R_v in order to decrease the cut-off frequencies such that the operational signals can be detected.

The high value of such resistances is impractical and may induce an unacceptable margin of error.

Figure 2 is a block diagram showing the principle of operation of a sensor 2 comprising a piezoelectric coaxial cable 4 as shown in figure 1, interconnected to an oscillator 11 and an impedance transformer 13, whereby the oscillator provides an alternating signal F_{test} at a frequency out of the range of frequency (i.e. bandwidth) of the operating signal $F_{operation}$.

Referring to figure 3, the cable is shown interconnected to an oscillator by a coupling capacitor C_o to the cable inner conductor 8. The cable has a length L_k having a capacitance C_k that is a function of this length. The capacitance C_k of the cable and coupling capacitor C_o determine, with the circuitry of the oscillator 11, the frequency of oscillation F_{test}. If the cable 4 is damaged, the capacitance C_k changes and the oscillator frequency is modified. For example if the cable is severed and therefore shorter, the capacitance C_k of the cable is smaller and the frequency of the oscillator increases. This deviation of the frequency F_{test} can be detected by an appropriate electronic analysis circuit of the sensor. A particularly simple self-testing means is thus provided. The embodiment of figure 3, however, has a disadvantage in that severance of a small piece of the cable proximate the end 12 may not sufficiently change the capacitance C_k so as to vary the frequency of oscillation in a manner that can be reliably detected. This can be overcome by providing a termination capacitor C_T between outer and inner electrodes 6,8 at the second end 12 of the cable 4 as shown in figure 4. The inductances and capacitors L_o and C_o could be tuned appropriately with the cable capacitance C_k and termination capacitor C_T to provide a resonating frequency out of the range of the operating frequency generated during use of the sensor. Such use may for example measure vibrations of a mass on a car seat. Self-testing can thus occur simultaneously to operation without interference.

Referring to figure 5, the embodiment of figure 4 can be modified by adding in series to the termination capacitor C_T, a termination inductance L_T. In this embodiment, the cable 4 merely acts as a conductor between the oscillator and series capacitor and inductance circuit C_T, L_T. By appropriate dimensioning of the oscillator to resonate with the termination circuit, damage to the cable would prevent

resonance. Detection of damage would thus be simplified to detecting the state of resonance (normal operation) or no resonance (damage).

Referring to figure 6, the sensor cable is represented as an electrical circuit 4 for connection to an operational amplifier with input resistance R_A. The cable generates a voltage during operation V_{piezo} and has a capacitance C_k (which may include the termination capacitance C_T) and a resistance R_K that represents the resistance of the dielectric 7 and other „leakage" resistances in parallel between the outer and inner conductors 8,6 respectively. An undamaged cable, has a dielectric with a resistance in the Giga-Ohm range such that the current flowing through the resistance R_K is substantially 0. Damage or humidity may lower the resistance R_K such that a leakage current (i_k) flows therethrough, thereby affecting the value of the operational voltage V_{piezo}. In other words the operational signal may be influenced leading to defective sensing. In order to detect a leakage current i_K as shown in figure 7, a voltage V_{ref} provides a DC offset voltage between outer and inner conductors that drives a leakage current i_K through the resistance R_K. If the resistance R_K is very high, as it should be with an undamaged cable, i_K is almost 0. The DC potential difference at the poles of the resistance R_a is therefore almost zero in the latter case. If the dielectric resistance R_K is reduced, the flow of leakage current i_K modifies the direct current offset voltage, enabling detection of the impaired dielectric or other leakage between outer and inner conductors.

Referring to figure 8, a circuit diagram of the sensor 2 is shown comprising various circuits that are indicated by the dotted lines as: the cable circuit 20; oscillator circuit 22; operational amplifier circuit 24; and impedance transformer and filter circuits 26,32. The oscillator circuit 22 comprises a differential stage oscillator with a frequency depending on the values of inductances L_o, C_o and the

capacitance C_k of the cable (which depends on the capacitance of the cable alone and any termination capacitors). The frequency of the oscillator may also depend on provision of a termination inductance according to the embodiment of figure 5. In the latter case, the oscillator circuit needs to be modified accordingly (e.g. by removing inductance L_o). The oscillator circuit 22 outputs a signal F_{test} that can be processed by the analyzing circuits of the sensor. The operational signal of the sensor cable (at point 10) is fed to an operational amplifier circuit 24 that comprises an operational amplifier A_o with a low pass filter 33 comprised of the circuit R_2,C_1 and R_1. The oscillator circuit 24 in the present example operates as a charge amplifier, however it is also possible to consider providing a voltage amplifier. A capacitor C_2 couples the amplifier output signal 30 to the output signal $F_{operation}$ whilst eliminating the DC signal. The operational output signal $F_{operation}$ is then fed to the sensor analyzing circuit. The low pass filter filters the oscillator 11 frequencies such that the operational output signal $F_{operation}$ is not influenced by the oscillation frequency (which operates out of the bandwidth of the operational signals generated by mechanical forces on the sensor cable).

The plus pole input 29 of the operational amplifier A_o is connected to a voltage source V_{ref} that creates a direct current offset voltage at the output 30 of the amplifier, which is connected to an impedance transformer 26. The impedance transformer comprises an amplifier A_3 having a gain of 1, the impedance transformer acting to decouple the operational signal from the DC output 35. After the impedance transformer, is a low pass filter 32. The low pass filter 32 substantially removes the operational frequency of the output 30 and provides the offset DC signal. The value of the DC signal is effected by leakage current (i_k) flowing through

the resistance R_K representing the cable dielectric, and should have the value of V_{ref} when the cable is undamaged.

CLAIMS

1. Sensor device comprising a sensor cable having electrodes separated by a dielectric, and self-diagnosis means, the self-diagnosis means comprising an oscillator circuit comprising an oscillator connected to an electrode and adapted to oscillate in conjunction with the cable, thereby producing a test signal at a frequency determined by the integrity of the sensor cable for detection of damage thereto, the cable providing inductance or capacitance forming part of the oscillator circuit.

2. The sensor device of claim 1 wherein the sensor generates an operational signal during normal operation for the purpose of determining the operational response of the sensor, and the oscillator generates a test signal that has a frequency out of the bandwidth of the operational signal when the cable is undamaged.

3. The sensor device of claim 2 wherein an operational amplifier circuit is provided to process the sensor operational signals, the operational circuit comprising a filter for filtering the oscillator signals.

4. The sensor device of any one of the preceding claims wherein the device comprises a direct current offset voltage circuit for detecting leakage currents between the electrodes.

5. The sensor device of any one of the preceding claims wherein the sensor cable comprises a termination capacitor between electrodes at an end of the cable, the capacitor forming part of the oscillator circuit.

6. The sensor device of any one of the preceding claims wherein a termination inductance is provided between electrodes at an end of the cable, the inductance forming part of the oscillator circuit.

7. The sensor device of any one of the preceding claims wherein an operational amplifier circuit is connected to one end of the cable for processing the sensor operational signals, the circuit comprising an operational amplifier

8. The sensor device of claim 7 wherein the operational amplifier circuit comprises a reference voltage at an input side of the operational amplifier, to create an offset direct current voltage at the output of the amplifier.

9. The sensor device of claim 7 or 8 wherein an input pole of the amplifier is set at a reference voltage to create an offset direct current voltage at the output of the amplifier.

10. The sensor device of claim 7,8 or 9 wherein the amplifier comprises a filter for eliminating the test signal from the operational output.

11. A sensor device constructed and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings

Application No:	GB 9720257.6	**Examiner:**	J. A. Watt
Claims searched:	1 - 11	**Date of search:**	23 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1U (UR2716, UR2718, UR2720, UR3100, UR3102, UR3108)

Int Cl (Ed.6): G01R 27/16, 27/18, 27/20, 31/00, 31/02, 31/08

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2123567 A	(REDLAND AUTOMATION) see page 1, lines 14 - 28	1
A	GB 1496151	(TELEPHONE CABLES) see page 1, lines 13 - 26	1
X	US 5463317	(BOEING) see whole document	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

DERWENT-ACC-NO: 1998-162167

DERWENT-WEEK: 199815

TITLE: Self testing piezoelectric cable sensor i.e. for vehicle airbag has oscillator circuit in parallel to normal operation, termination capacitor and DC offset voltage bay be applied between electrodes

INVENTOR: BERGNER B

PATENT-ASSIGNEE: WHITAKER CORP[WHITN]

PRIORITY-DATA: 1996GB-019892 (September 24, 1996)

PATENT-FAMILY:

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GB 2317707 A	April 1, 1998	EN

APPLICATION-DATA:

PUB-NO	APPL-DESCRIPTOR	APPL-NO	APPL-DATE
GB 2317707A	N/A	1997GB-020257	September 24, 1997

INT-CL-CURRENT:

TYPE	IPC DATE
CIPS	G01R31/28 20060101

ABSTRACTED-PUB-NO: GB 2317707 A

BASIC-ABSTRACT:

The sensor (4) has a sensor cable with two electrodes (6, 8) separated by a dielectric. An oscillator circuit, with an oscillator (11) connected to an electrode, oscillates in conjunction with the cable. The oscillator circuit is in parallel to the normal operation.

The cable provides an inductance or capacitance part of the oscillator circuit. The oscillator circuit produces a test signal at a frequency determined by the integrity of the cable for detecting damage to it. A direct current offset voltage may be applied to the cable to detect leakage currents.

USE - Sensing presence of someone within the seat of the vehicle.

ADVANTAGE - Operates rapidly, reduction in dielectric resistance can be detected and can ensure sensor cable is in tact over whole length in a simple and reliable way.

CHOSEN-DRAWING: Dwg.4/8

TITLE-TERMS: SELF TEST PIEZOELECTRIC CABLE SENSE VEHICLE AIRBAG OSCILLATOR CIRCUIT PARALLEL NORMAL OPERATE TERMINATE CAPACITOR DC OFFSET VOLTAGE BAY APPLY ELECTRODE

DERWENT-CLASS: S01 U23 V06 X12 X22

EPI-CODES: S01-G04; U23-A01A; V06-L01A2; X12-D03J; X12-G01C; X22-X06D;

SECONDARY-ACC-NO:

Non-CPI Secondary Accession Numbers: 1998-129052